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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G05B 19/35

A1

(11) International Publication Number: WO 97/21154

(43) International Publication Date: 12 June 1997 (12.06.97)

(21) International Application Number: PCT/BG96/00017

(22) International Filing Date: 29 November 1996 (29.11.96)

(30) Priority Data:
100184 1 December 1995 (01.12.95) BG

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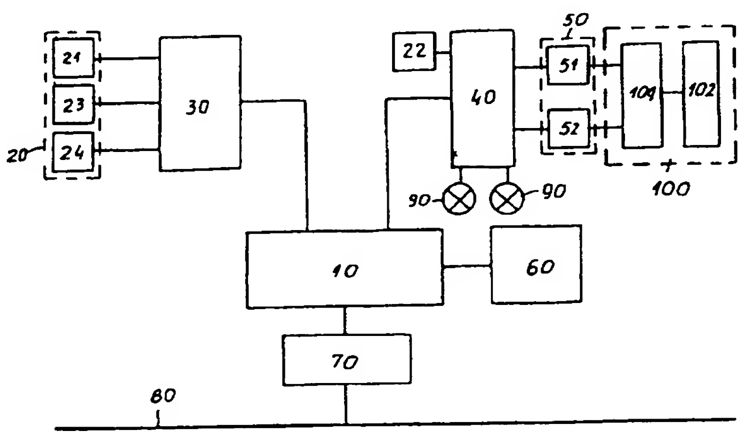
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: AUTOMATIC SYSTEM AND METHOD FOR REGULATION OF THE OPERATION OF AN AUTOMATIC VALVE



(57) Abstract

The invention relates to an intelligent automated system for the control of the operation of an automatic valve (100), and to a method for regulation and controlling of at least one valve (101) connected to an actuator (102). The system comprises at least two inputs (21, 23), one of which (21) is used to determine the position within a time reference, and the other (23) is used to determine noise in relation to the position of the actuator (102) and the valve (101). The inputs (21, 23) are connected to actuator control means (50) through an analog-to-digital converter (30) connected in turn to a microprocessor control device (10). The microprocessor control device (10) is connected to an output (40) and to a communication transmitter (70) used to coordinate the operation of the system elements and to provide communications to an external communications network (80). The microprocessor control device (10) has the capability to process data from at least two inputs (21, 23), calculating the resistance torque of the automatic valve, comparing the measurement data to a data base stored in a nonvolatile memory (60) and calculating the desired position. The system is connected to a LONWORKS network.

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AUTOMATIC SYSTEM AND METHOD FOR REGULATION OF THE OPERATION OF AN AUTOMATIC VALVE

FIELD OF THE INVENTION

The present invention generally relates to an automated system and to a method for regulation of an automatic valve, and more specifically to an intelligent control system, capable to detect the environment, and to a method for the regulation and the controlling of the operation of an automatic valve connected to an actuator.

BACKGROUND OF THE INVENTION

There are valves with a wide application in practice whose position is regulated by a number types of actuators. In order to automate and enhance the precision of the process of the actuator direction and velocity regulation, various type of control devices based on electronic means are employed.

An electro-hydraulic servo system for the regulation of the positioning of automatic valves or of other servo units is known from EP 0294918, having automatic calibration capabilities. The system comprises input determining the present position of the actuator using voltage modulation, also a microcontroller for the activation of the actuator in an automatic calibration mode in order to obtain data from the actuator and memory for storing said calibration data. The system further comprises a microprocessor for accessing said calibration data from the memory and calculating a desired position of the actuator from said calibration data, further comprises an output for generating a signal dependant on the calibration data when a difference exists between said determined present and the desired position of the actuator, and also actuator control means which are actuated by the output signal and which force the actuator to acquire the desired position.

The method which is employed to realize the electro-hydraulic servo system as described herein consists of an initial determination of the OPEN-CLOSED-OPEN characteristics, the determination of the position of the valve as connected to the actuator. This process is realized by rotating the servo system to a fully opened state, also in the transmission of the measurement data in a digital format to a microcontroller, also the transmission of these data along a communication network to a microprocessor, which in turn is storing these data in a nonvolatile memory. After this the servo system is forced to rotate to a fully closed position and the measurement data in a digital format are transmitted in a similar manner to the microcontroller and from there along the communication network to the microprocessor, which is again storing these data in a nonvolatile memory. After this process a control signal converted into a digital format is transmitted along the

communication network, the actual position is measured and the data are converted in a digital format. after which the control signal data are compared to the calibration data retrieved from the nonvolatile memory and to the data from the measurement of the actual position, and in case of differences an output signal is transmitted to the actuator for effecting a displacement in the desired direction.

This known solution has the disadvantage that the system is operated in an automatic mode only when a new control signal is emitted. Said system is not provided with sel test capabilities and is able to process data only from a single position gauge which restricts its functional capabilities and the reliability of the system.

SUMMARY OF THE INVENTION

The object of the present invention is to provide an automated system and a method for the regulation of the operation of an automatic valve with the aim to enhance the functional capabilities of the system and to ensure optimal operating conditions.

Another object of the present invention is to provide an automatic system for the regulation of an automatic valve which would have an enhanced reliability.

Still another object of the present invention is to simplify the system so that it could be designed by using conventional standardized devices.

According to the invention, an automatic system is provided for regulation of the operation of at least one automatic valve connected to an actuator, which system comprises an input for determining the position and the resistance torque of the actuator, a second input for a simultaneous measurement of the noise emitted by the fluid flowing through the valve and of the noise emitted by the actuator. There may be a third input for measuring the voltage fed to actuator control means. The first two inputs are connected to the actuator control means through an analog-to-digital converter for transforming the signals from the input into a digital format. The converter is connected to a microprocessor control device for detection of the environment and for regulating the actuator control means. The environment includes at least the type of the valve and of the actuator, and the current state of the system. The detection and the regulation are made by automatically operating the actuator control means through a calibrating sequence of positions of the valve as connected to the actuator for obtaining of a time relevant data base. The microprocessor control device serves also for a simultaneous processing and comparison of the data fed from all inputs to the data base and for calculating the desired position from the data about the measured position and the data base. The microprocessor control device is also connected to an output for generating a signal when a difference exists between the data about the measured position and

the data base, said output is connected to the actuator control means which are actuated by the output signal. The microprocessor control device is also connected to a communication transmitter coordinating the operation of the system elements and for communicating with an external communication network used for the transmission of the control signals and of alarm signals in case of both reversible and irreversible failures in the operation of the valves as connected to the actuators. According to one embodiment of the system the input for determining the position and the resistance torque of the actuator is of the contactless type. In one of the variants of the system the contactless input for determining the position of the actuators represents a magnetic-resistor type of sensor. In addition the system comprises circuits for a temperature offsetting of the data from the magnetic-resistor sensor depending on the ambient temperature.

In one embodiment of the invention the external communications network is connected to the power supply terminals of the system.

Another embodiment of the system comprises an indicator for local signaling in case a signal is transmitted to the actuator control means and also in case any trouble is detected regarding system operation.

According to the invention, a method for regulating the operation of an automatic valve connected to an actuator is provided, including the steps of an initial sampling of the characteristic OPEN-CLOSED-OPEN curves, the determination of the position within a time reference and in relation to the noise emitted by the valve as connected to the actuator, the process executed by emitting commands to the actuator to successively drive the actuator from a closed state to an open state of the valve, while the data are being stored in a nonvolatile memory, after which the valve is regulated from an open to a closed state and again the data are fed to a nonvolatile memory. After that the position, the resistance torque of the valve as connected to the actuator, the noise emitted by the fluid flowing through the valve and the noise emitted by the actuator being measured simultaneously and at a rate consistent with the sampling rate. The voltage fed to the actuator control means may be measured as well, and all measurement data are converted from the analog into a digital format by an analog-to-digital converter, after which all measurement data are compared with the calibration data and with the data base containing information on variables. When a control signal for the position of the valve is sent through the external communication network the signal data are stored in a nonvolatile memory in a digital format, and the control signal is processed by actuation the actuator control means. After that, the measurement data about the actual position and the resistance torque of the valve as connected to the actuator are compared to the control signal data and in case of deviations an alarm signal is transmitted along the external communications network, the indicator is actuated

and/or a command is emitted to actuate the actuator control means to compensate for the deviation.

The proposed automatic system for regulation of the operation of an automatic valve allows for the continuous supervision and monitoring of both the operation of the valve as connected to the actuator and the state of the separate modules within the system, and the emerging temporary or incident errors are corrected and/or an alarm signal is emitted which enhances the functional capabilities of the system, allows for a better time and labour efficiency and provides for optimal operating conditions.

By processing and comparison of the data from at least two independent contactless inputs in the embodiment where the inputs are of a contactless type, an initial detection of the valve type and of the relevant actuator type is performed and their operational states are analyzed in terms of more than one variable the security and the overall reliability of the system is also enhanced.

The system is intended as a modular structure which shortens the commissioning period, guarantees a high degree of serviceability under normal conditions which serves as one more factor for an increased reliability.

The presence of temperature error offsetting increases the operational accuracy of the system.

The connection of the external communications network to the system power supply simplifies the installation of the system, decreases the length of the cable which leads to savings in time, materials and labour. A connection between the independently controlled valves is provided which turns the system into a decentralized structure.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the characteristic OPEN-CLOSED-OPEN curve of a ball valve.

Figure 2 shows the characteristic OPEN-CLOSED-OPEN curve of a butterfly valve.

Figure 3 shows a sample of the OPEN-CLOSED-OPEN noise characteristics.

Figure 4 shows the curves with and without temperature compensation of a magnetic-resistor type of sensor.

Figure 5 shows the hardware block diagram of an automatic system for the regulation of a valve connected to an actuator.

Figure 6 shows the block diagram of the microprocessor used in the automatic system shown on Figure 5.

Figures 7a and 7b show a principle electric circuit diagram of the system shown on Figure 5 with a position sensor of a magnetic-resistor type and a pneumatic actuator, operated by electric flow-switches.

Figure 8a and 8b show the algorithm of the system shown on Fig. 5.

DETAILED DESCRIPTION OF THE INVENTION

Figures 1, 2, 3 and 4 show various characteristic curves which may be used as part of the system data base.

Figure 5 shows the hardware block diagram of one embodiment of the automatic system according to the invention where the microprocessor control device used for detection of the environment and for the regulation of a valve as connected to an actuator is designed as a microcontroller 10. The system comprises inputs 20, together, respectively, with a position sensor 21, voltage measuring devices 22, a noise sensor 23 and a temperature sensor 24, which are connected through an analog-to-digital converter 30, the microcontroller 10 and an output 40 for generating a signal to actuator control means 50 which are used to regulate the actuator. The actuator control means 50 in this embodiment are electric valves 51 and 52, but others can be provided for depending on the type of the actuator. The microcontroller 10 is connected to the nonvolatile EEPROM memory 60 which is used to store data and the firmware, as for example its algorithm is shown in Figs 8a and 8b. Through a communication transmitter 70 for coordination of the operation of the system elements, the microcontroller 10 connects to an external communications network 80, for instance LONWORKS, and receives control signals and transmits data and alarm signals in case of both reversible and irreversible failures in the operation of the valves as connected to the actuators. The output 40 is connected to an indicator 90 which is used to indicate the emergence of failures in the system and to emit an alarm signal, the indicator 90 for example is designed on the basis of two light emitting diodes 91 and 92. The output 40 incorporates the voltage measuring devices 22 used for the measurement of the output signal. The actuator control means 50 are connected to the automatic valve which consists of a valve 101 connected to an actuator 102.

According to Fig. 6 the microcontroller 10 may incorporate three microprocessors - 11, 12 and 13, microprocessor 11 serving for communicating with the external communications network 80, microprocessor 13 used for monitoring, regulation and issuing of commands, and microprocessor 12 used as a link between the other two microprocessors. The microcontroller 10 has an adapting device 14 which is connected to the external communication network 80, an input-output device 15 connected to a counter and a timer for the generation of discrete signals, devices 16 for synchronizing the operation of the microcontroller, as well as devices 17 for connection to the external memory 60. According to the embodiment as shown in Fig. 6 the microcontroller 10 comprises two memories, respectively the

RAM 18 and the EEPROM 19. The microcontroller 10 may be based for example on a MOTOROLA integrated circuit a catalogue number NEURON 3150.

In the exemplary principle electric circuit diagram shown on Fig. 7 the position sensor 21 is designed as a magnetic-resistor measuring bridge circuit, and the voltage measuring devices 22 are incorporated within the input 40 which is used for the generation of an output signal. In this embodiment the output 40 is a power pulse transducer based on an integrated circuit, which may be an integrated circuit with a catalogue number LDM 18400 manufactured by NATINAL SEMICONDUCTORS, while a microphone is used as a noise sensor. The analog-to-digital converter 30 is designed as an integrated circuit, which may be an integrated circuit with a catalogue number AD 7714 manufactured by ANALOG DEVICES. The nonvolatile memory 60 connected to microcontroller 10 may also be designed on the basis of a standard integrated circuit, and in the shown embodiment the transmitter 70 which is used to provide communication to an external communications network, in this specific case a LONWORKS, and is designed on the basis of an integrated circuit with a catalogue number LPT-10 manufactured by ECHELON. The temperature offsetting devices, in this specific embodiment the temperature sensor 24 may be based on a standard sensor of the type LM 35 manufactured by NATIONAL SEMICONDUCTORS.

The method which is the subject of this invention may be exemplified by the operation of the system as shown on Figure 5, which system is controlled by a programme whose algorithm is shown on Figs. 8a and 8b. This algorithm shows the presence of more than one input signal, which input signals are processed in such a way as to provide an automatic monitoring in a dialogue mode of the changes in the environment and in the operation of the system itself. A mode of an initial calibration is also provided for as well as of automatic recognition of the type of valve and the type of actuator.

According to the algorithm shown on Figs. 8a and 8b the method according to the invention is initialized by switching the system to a power supply. After this it is determined if the hardware configuration is known (step S10). The configuration is considered unknown in the initial switching and the method is going on at the branch "NO" of the block of code S10 for an automatic calibration. At the time of automatic calibration the valve 101 is opened or closed by a command from the microcontroller 10 to the output 40 and to the actuator control means 50 . The open state of the actuator 102 is measured (step S12) together with the noise emitted during the operation of the controlled valve 100 until it reaches its fully open state, and the signals are converted into a digital format and are stored into the nonvolatile memory 60 (step S13). After this the microcontroller 10 issues a command to close valve 101, and the position and noise data for the fully closed state are measured in

a similar way (step S14) and are stored in the memory 60 (step S15). A command is issued for a selfcalibration of the gain (step S16) of the position regulator and the OPEN-CLOSED-OPEN curves are sampled within a time reference (step S18). The measurement data are stored in the memory 60. Using the characteristic curves which were derived in this way and their comparison to a data base stored in the memory 60 containing similar curves the system automatically detects the design type of valve 101 and the type of the actuator 102. When comparing for instance the characteristic curves shown on Figs. 1 and 2 it becomes obvious that the curves are different for the different types of valves. Judging by the asymmetry of the characteristic curves for the OPEN and CLOSE operation of the valve 101 it is possible to detect the type of the actuator 102, for instance whether it is spring-loaded or not, and thence to judge about the number and/or the type of actuator control means 50 necessary for its actuation. The changes in the torque at the extreme positions of the valve 101 as shown on the characteristics curves provide information about the OPEN-CLOSED position of the actuator 102. The displacement speed as represented by the characteristic curves provides information about the proper choice of the actuator 102 and eventually for any deviations from its nominal operational characteristics. The noise characteristics during opening or closing is used to determine the cavitation zone which is fixed into the position characteristic, and also allows to judge about the state of the valve 101 and more specifically whether it is sufficiently packed when closed.

After a single calibration (step S10) the temperature is continuously measured over specified intervals of time (steps S20,S21), and the measurement data are converted into a digital format after which they are compared to the temperature compensation data base and a signal is emitted to compensate the deviation (steps S30,S31). The actual value of the resistance torque of the automatic valve 100 is measured within the same cycle (step S30), these data are further converted into a digital format by the analog-to-digital converter 30 and are compared with position data acquired during calibration. The noise emitted by the fluid flowing through the valve and by the actuator is measured at the same time (step S30) and a comparison to calibration data is made in a similar way. In case of the emergence of a problem the voltage fed to the actuator control means 50 is also measured (step S34) and the data are compared to the admissible extreme values as stored in a variables data base. The deviations are calculated and compared by the microcontroller 10. A command is issued to the actuator control means 50 for compensating the deviations and the indicators 90 are switched on (step S50). In case the difference cannot be compensated the indicators 90 remain on and an alarm signal is sent through the external communications network. This state indicates the emergence of cavitation, of mechanical obstructions in the valve 101 or

in the actuator 102, of a pressure drop in case of using of a pneumatic system actuator 102, as well as other mechanical problems (step S51).

With reference to Figs. 5a and 5b, when a control signal is fed through the external communication network 80 to change the position of the valve 101, this signal data are stored in a digital format into the EEPROM memory 19, the actuator control means 50 are actuated and the command is executed. After this the data from the measurement of the actual state of the automatic valve are compared to the data from the command signal and in case of a deviation a command is issued to actuate the actuator control means 50 to compensate the difference, and at the same time the indicators 90 are switched on. In case the difference cannot be compensated the indicators 90 remain activated and an alarm signal is sent through the external communication network 80.

The voltage to the actuator control means 50 is measured by means of integrated circuits incorporated in the devices 40 used to generate output signals, and after a comparison with the data base and in case of a deviation beyond the admissible margins the indicator 90 is activated and an alarm signal is sent through the external communication network 80. In case of differences beyond the admissible margins the system is adapted to work in EEXI fire-precaution operation mode. The system automatically detects whether to remain on or to switch off automatically in order to avoid permanent damages.

The present invention has been presented in a principle design which does not serve as a delimiter of the inventor's ideas but should serve as an illustration only, the scope of the invention being determined only by the claims as enclosed herewith.

CLAIMS

1. An automatic system for the regulation of the operation of an automatic valve connected to an actuator, whereas the system comprises input for determining the current position of the actuator, whereas said input is connected to actuator control means for regulating the actuator through a microprocessor control device for controlling the actuator in a mode conductive to the automatic calibration in terms of position, characterized by the fact that further comprises at least one more input (22) for the measurement of the voltage supplied to the actuator control means (50), and/or an input (23) for the measurement of noise which inputs (21, 22, 23) are connected to the actuator control means (50) through an analog-to-digital converter (30) whereas the converter (30) is connected to a microprocessor control device (10) connected to at least one nonvolatile memory (60) and whereas the microprocessor control device (10) is used to detect the environment through a simultaneous processing and comparison of data from the input devices (21, 23) used to determine the resistance torque in terms of position and in terms of the noise emitted by the actuator by calculating the desired position of the actuator (102) as a difference between the measurement data and the information contained in a data base, whereas the microprocessor control device (10) is connected to an output (40) for generation of a signal which effects the compensation of the differences, whereas said output (40) is connected to the actuator control means (50), whereas the microprocessor control device (10) is connected also to a communications transmitter (70) used for coordinating the operation of the system elements and for providing communications to an external communication network (80).

2. An automatic system for the regulation of an automatic valve as described in Claim 1, characterized by the fact that the input (21) for determining the position and the resistance torques of the actuator (102) is of the contactless type.

3. An automatic system for the regulation of an automatic valve as described in Claim 2, characterized by the fact that the contactless input (21) is of a magnetic-resistor type.

4. An automatic system for the regulation of an automatic valve as described in claims 1, 2 and 3, characterized by the fact that the external communications network (80) is connected to the power supply terminals of the system.

5. A method for regulating the operation of an automatic valve connected to an actuator, whereas the method involves an initial automatic calibration which is performed by recording the characteristic OPEN-CLOSED-OPEN curves of the actuator in terms of the actuator position, whereas the data are stored into a nonvolatile memory in a digital format, whereas a control signal is emitted through the external communication network and is converted into a digital format, whereas the actual position of the actuator is measured and the data are converted into a

digital format, whereas the measurement data are compared to the control signal data and to that calibration data in a microprocessor control device, whereas in case of the emergence of deviations a control signal is emitted to the actuator to compensate for the deviations, characterized by the fact that:

a) the automatic calibration is performed by measuring the position within a time reference by calculating the resistance torque of the automatic valve (100) and by measuring the noise in terms of the position of the valve (101) as connected to the actuator (102);

b) the data are stored in a digital format into a nonvolatile memory (60);

c) the position, the resistance torque and the fluid noise are measured continuously at a rate equal to the sampling rate;

d) the data as converted into a digital format is compared to the calibration data and to the information contained in a variables data base;

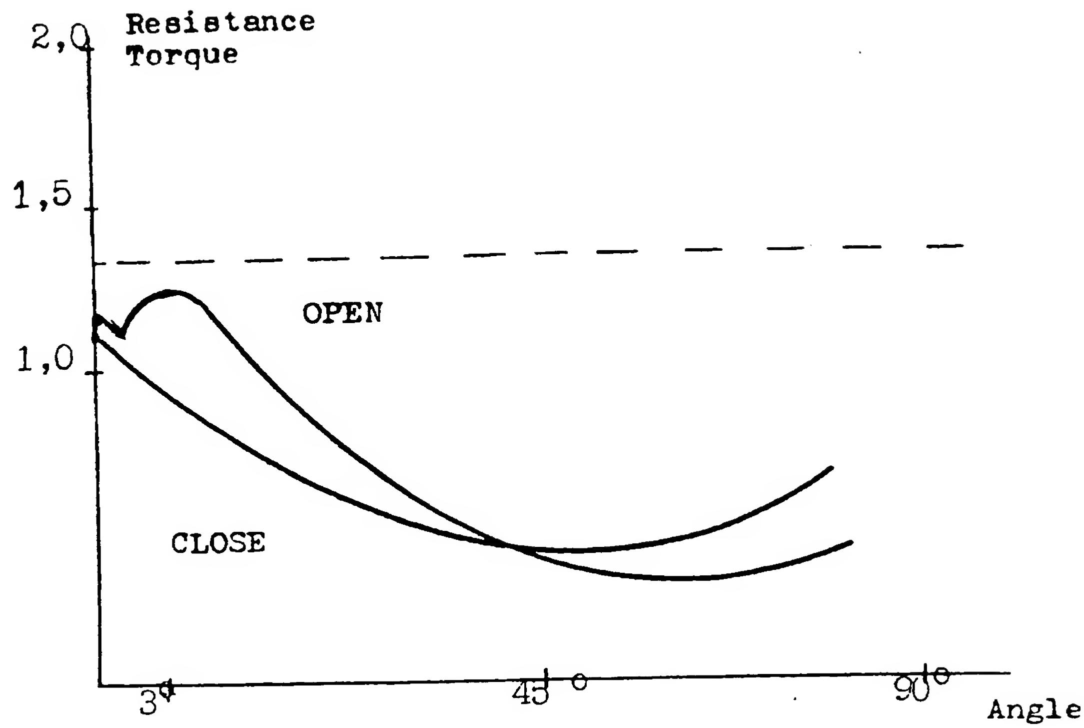
e) said data are transmitted through a communication network (80);

f) the data from the control signal is stored in a digital format into a nonvolatile memory (60);

g) in the case of the emergence of a deviation between the data representing the actual position, the resistance torque and the noise emitted by the valve (101) as connected to the actuator (102) and the data representing the control signal an alarm signal is sent through the external communication network (80) and/or a command is issued to compensate the deviations, and

h) a continuous temperature compensation is performed for the influence of the ambient temperature on the inputs.

6. A method for the regulation of an automatic valve as described in Claim 5, characterized by the fact that continuously and at a rate consistent with the sampling rate the voltage fed to the actuator control means (50) is measured and in case of a change in this voltage an alarm signal is emitted and/or the system is automatically switched off.


Resistance Torque
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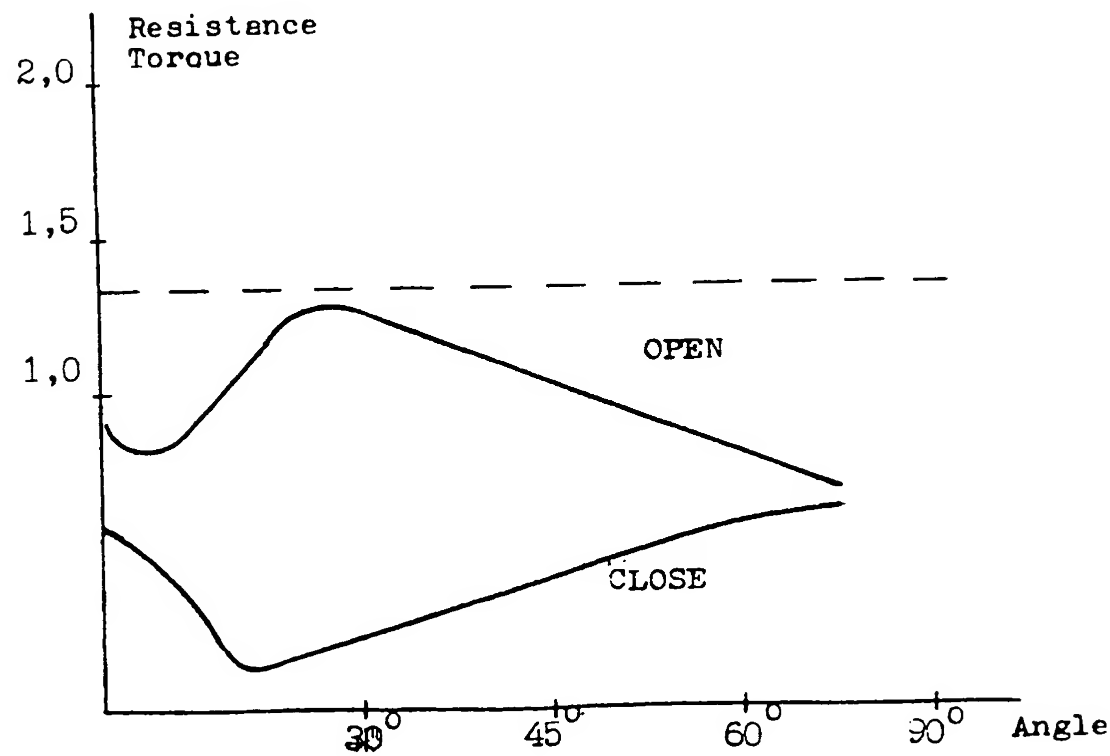
1,5
1,0
OPEN
CLOSE
3°
45°
90°
Angle

Fig. 1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1,5
1,0
OPEN
CLOSE
30°
45°
60°
90°
Angle

Fig. 2

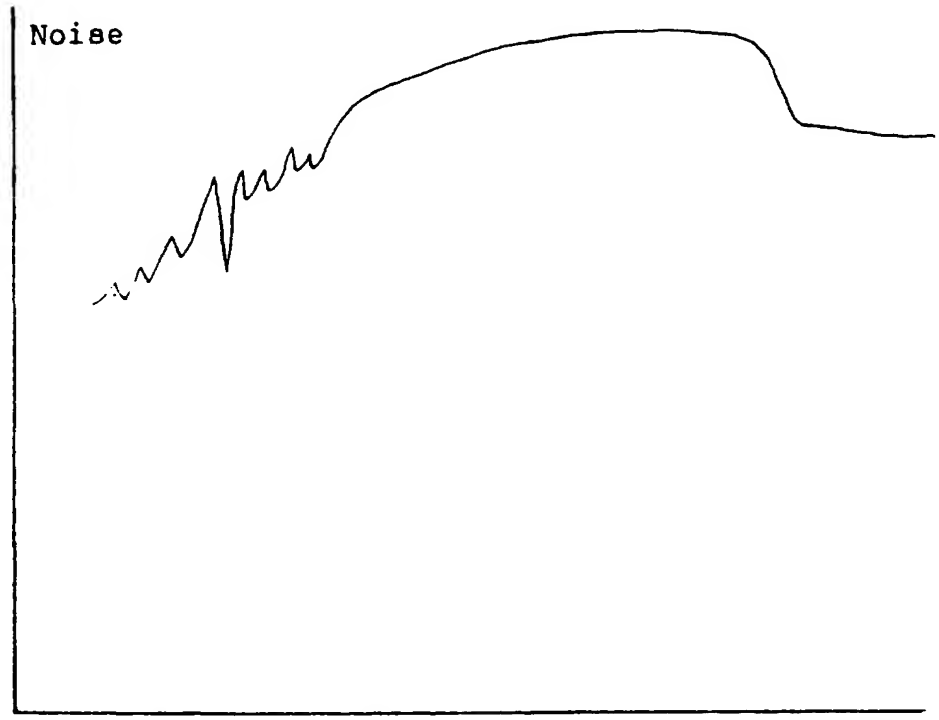

Noise
Position

Fig. 3

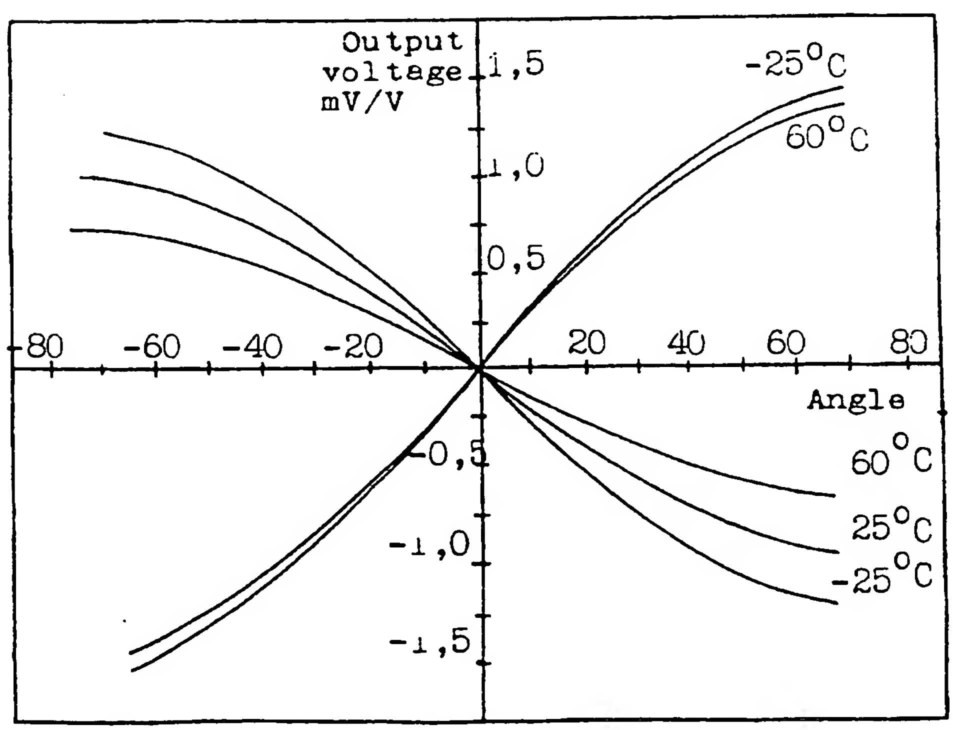

Output
voltage
mV/V
1,5
1,0
0,5
-0,5
-1,0
-1,5
-80
-60
-40
-20
20
40
60
80
Angle
-25°C
60°C
60°C
25°C
-25°C

Fig. 4

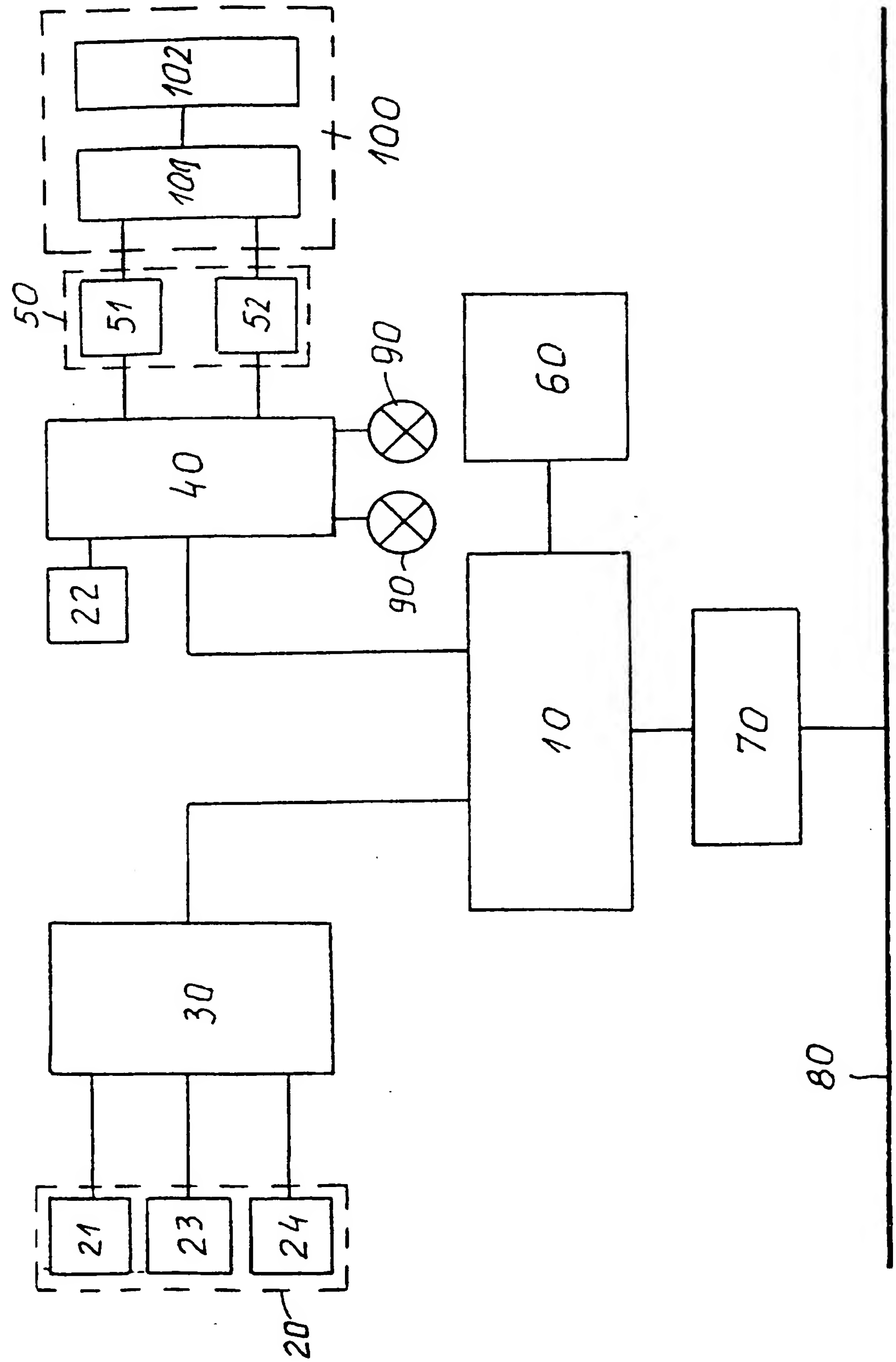


Fig. 5

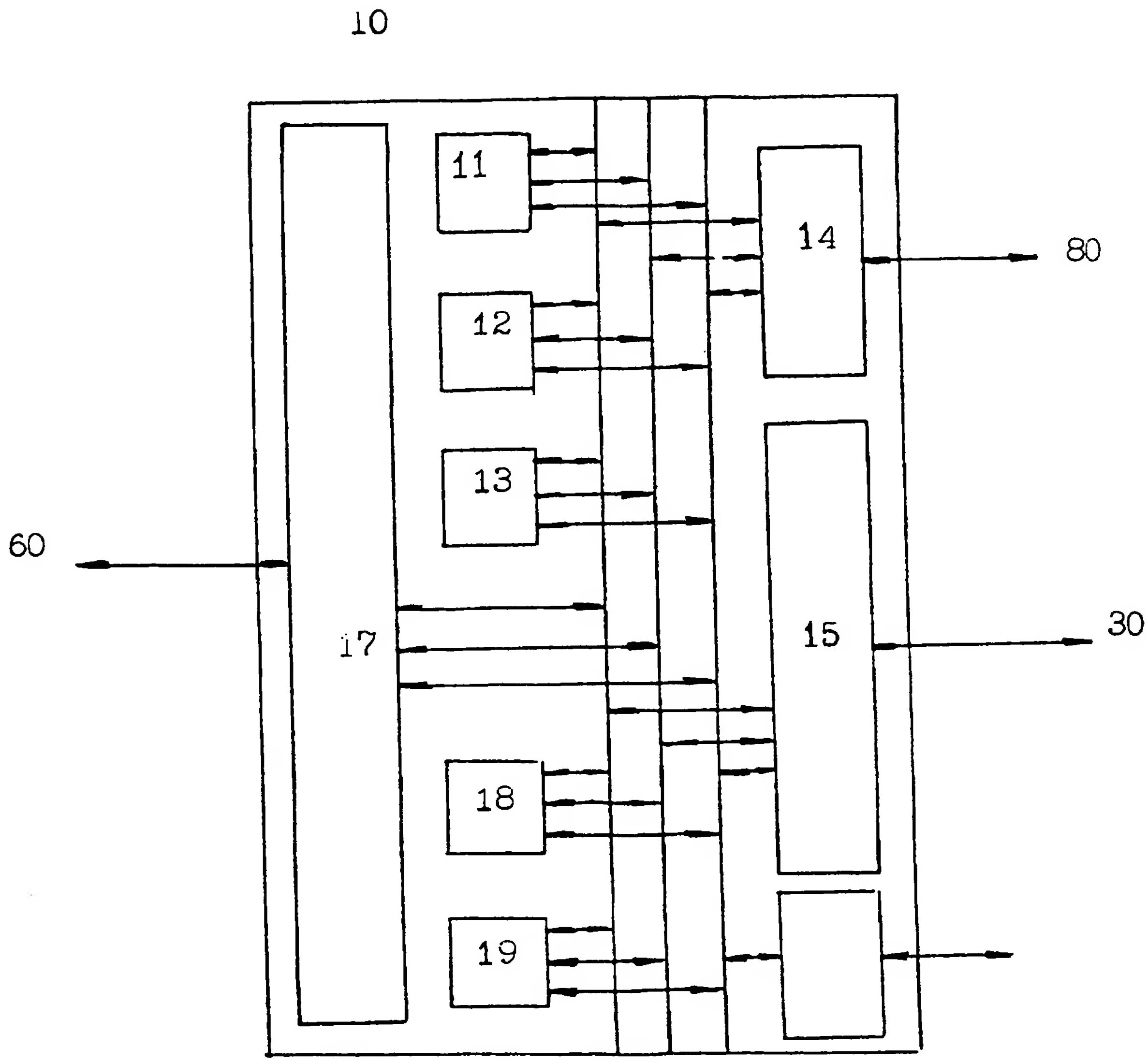


Fig. 6

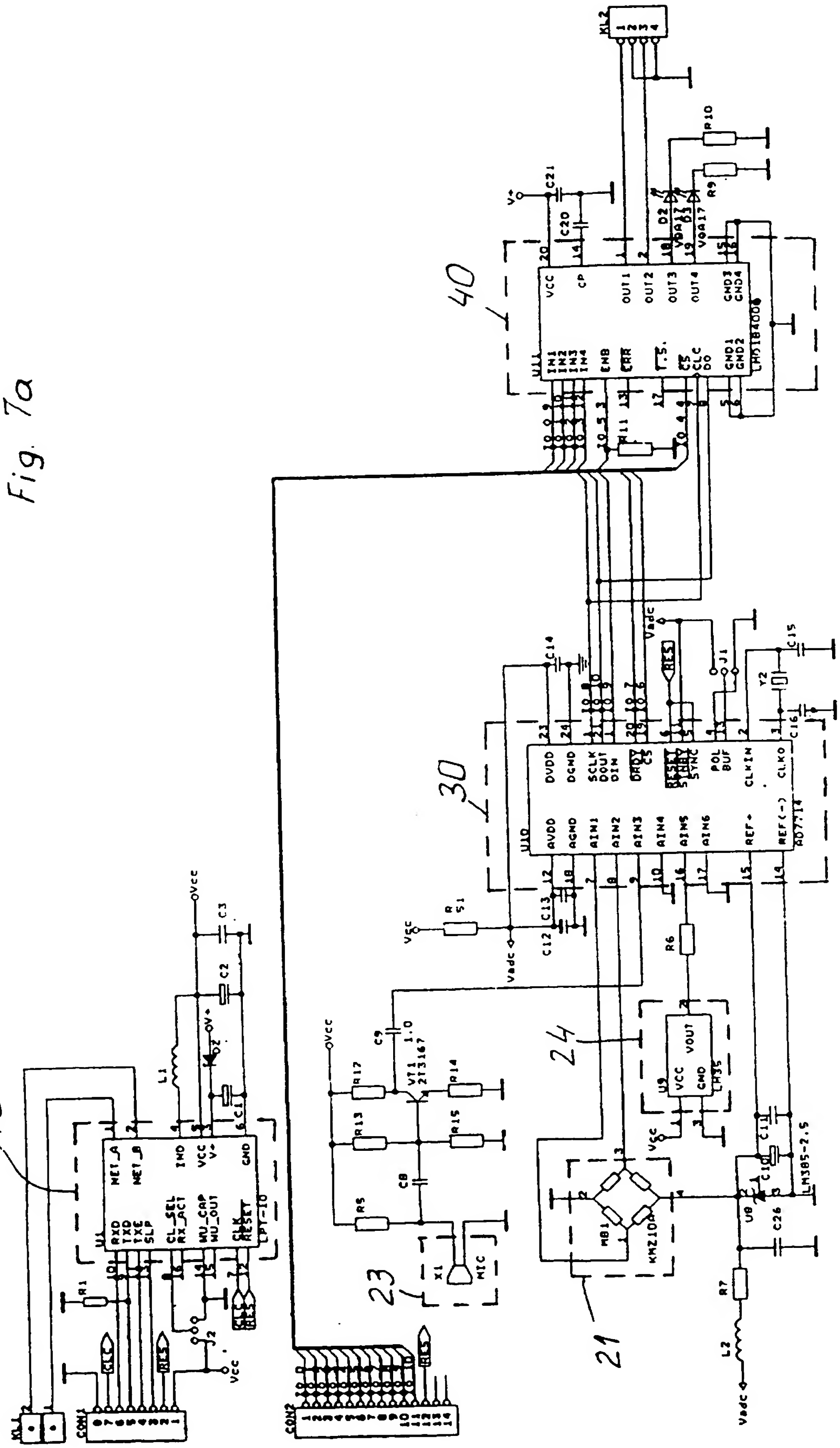


Fig. 7a

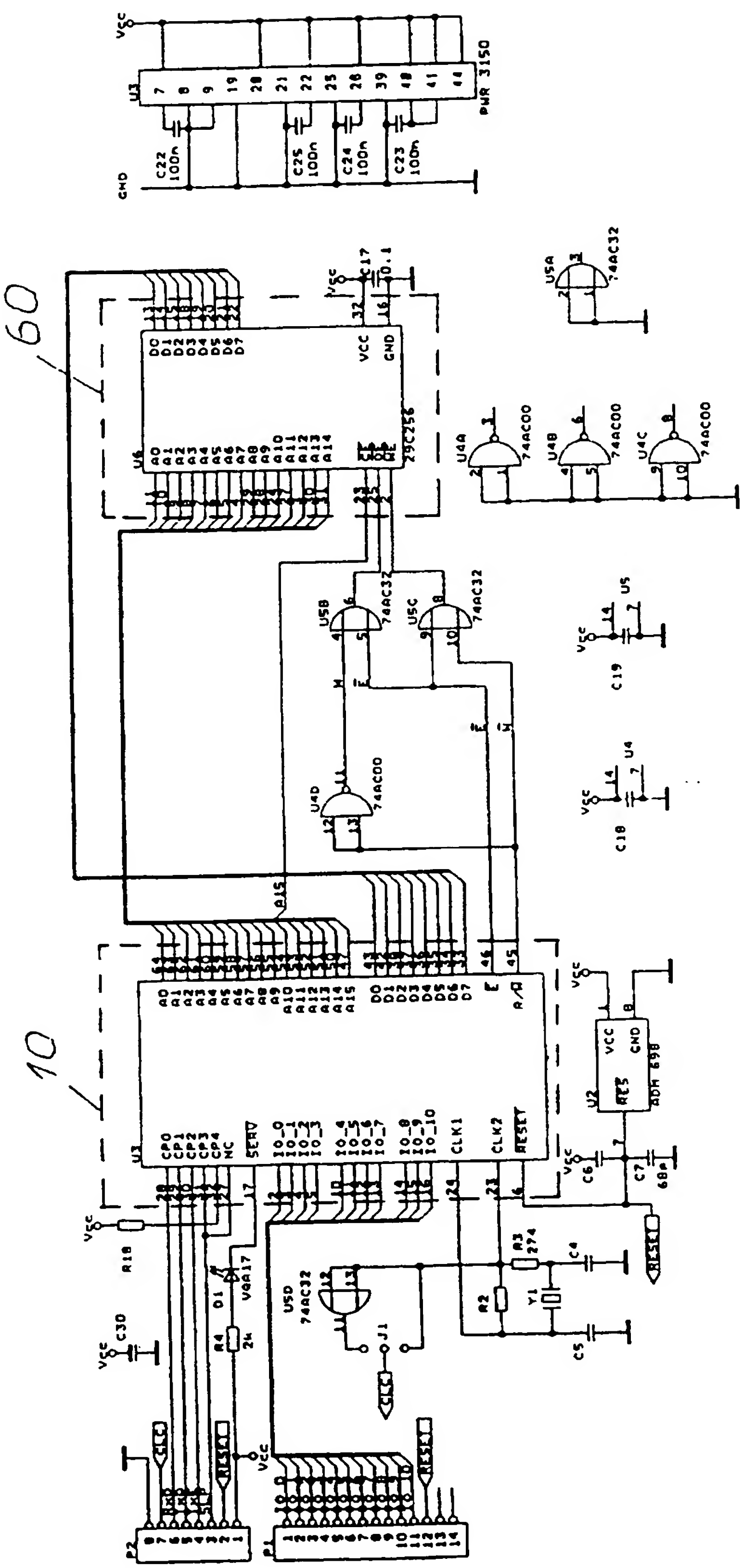


Fig. 7B

Fig. 8a

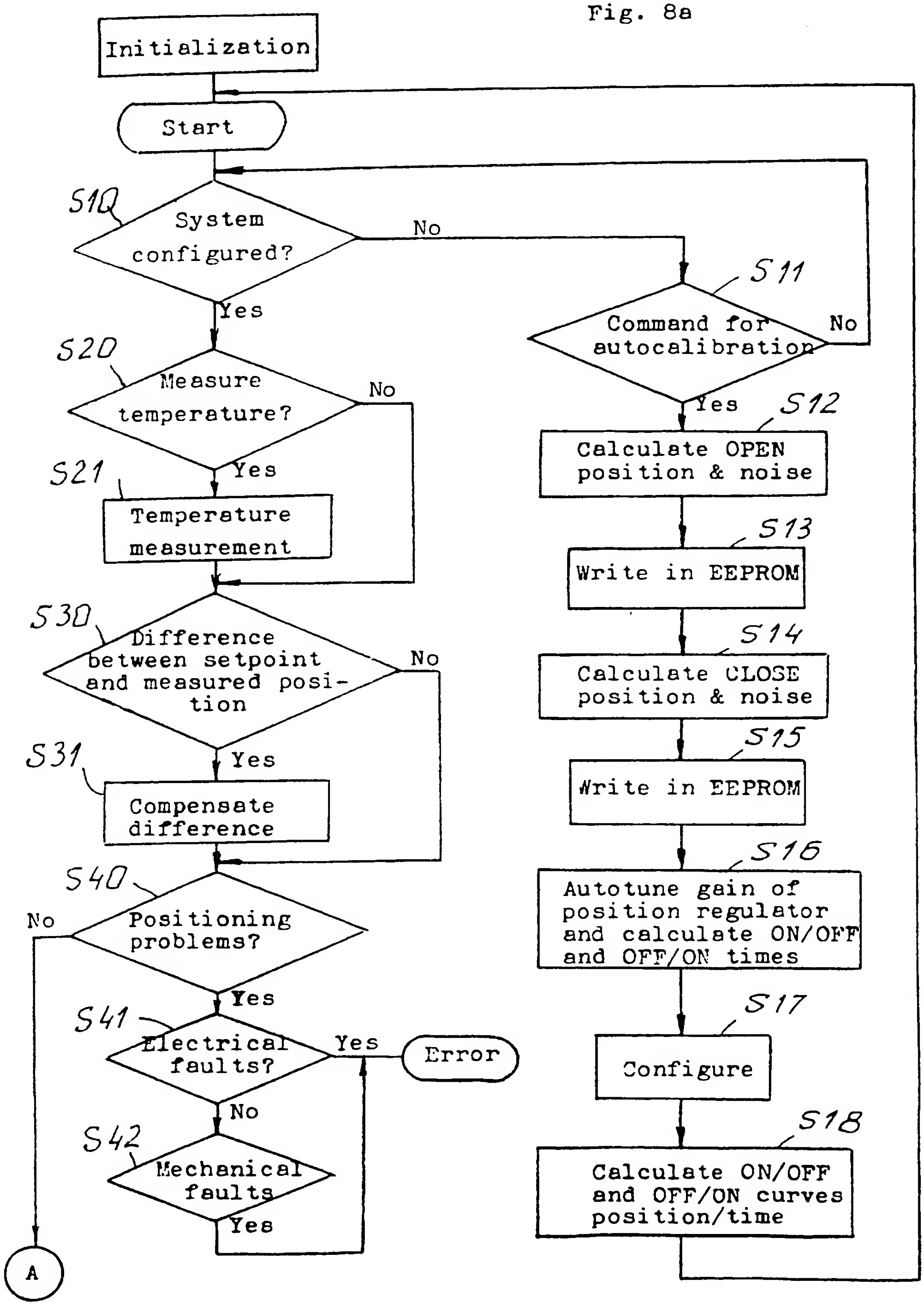
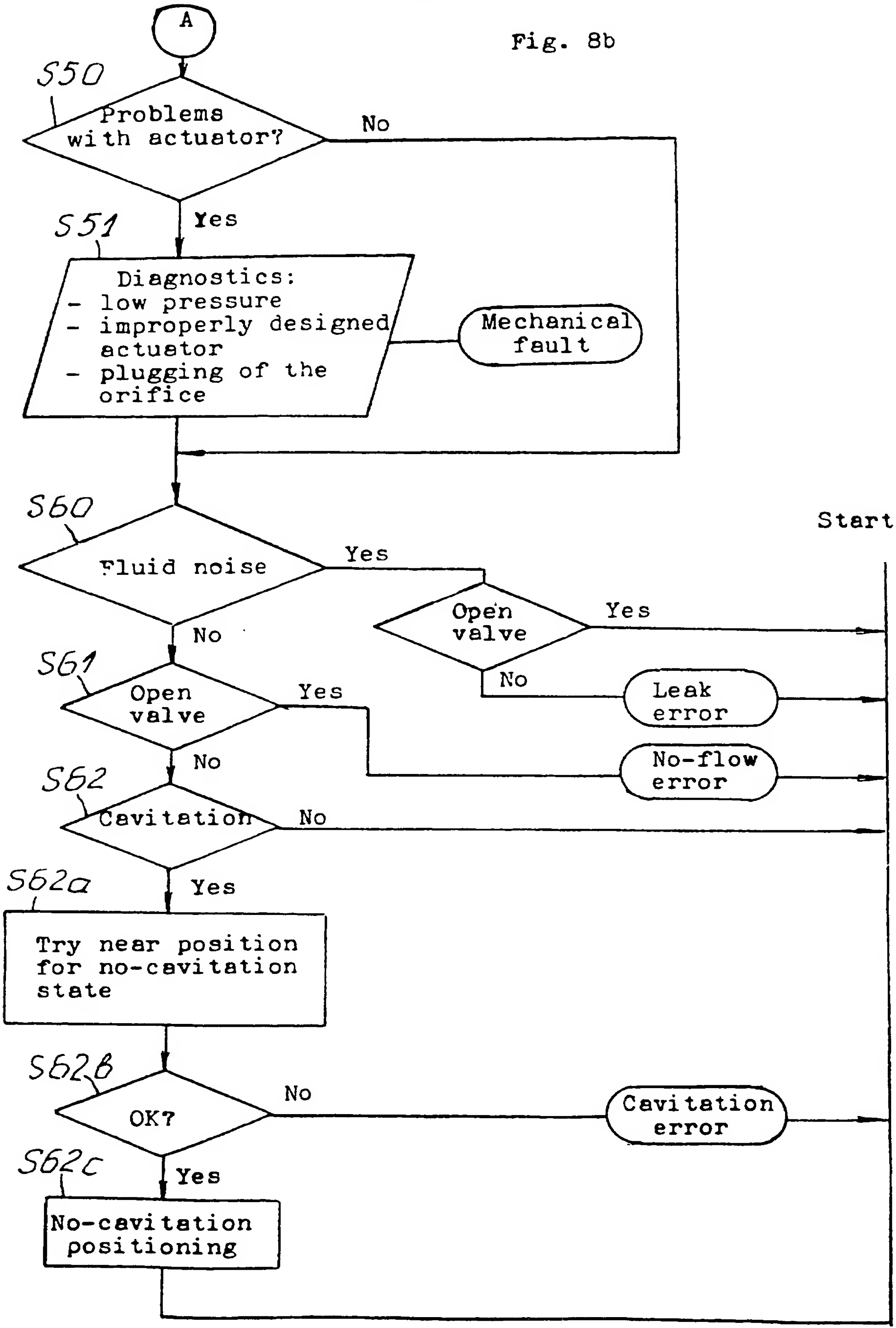

Initialization
Start
S10
System configured?
No
Yes
S11
Command for autocalibration
No
Yes
S12
Calculate OPEN position & noise
S13
Write in EEPROM
S14
Calculate CLOSE position & noise
S15
Write in EEPROM
S16
Autotune gain of position regulator and calculate ON/OFF and OFF/ON times
S17
Configure
S18
Calculate ON/OFF and OFF/ON curves position/time
S20
Measure temperature?
No
Yes
S21
Temperature measurement
S30
Difference between setpoint and measured position
No
Yes
S31
Compensate difference
S40
Positioning problems?
No
Yes
S41
Electrical faults?
Yes
Error
No
S42
Mechanical faults
Yes
A

Fig. 8b


A
S50
Problems with actuator?
No
Yes
S51
Diagnostics:
- low pressure
- improperly desegned actuator
- plugging of the orifice
Mechanical fault
S60
Fluid noise
Yes
Start
Open valve
Yes
No
No
S61
Open valve
Yes
Leak error
No
S62
No-flow error
Cavitation
No
S62a
Yes
Try near position for no-cavitation state
S62b
No
OK?
Cavitation error
S62c
Yes
No-cavitation positioning

INTERNATIONAL SEARCH REPORT

International Application No
PCT/BG 96/00017

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G05B19/35

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 294 918 A (BABCOCK & WILCOX CO.) 14 December 1988 cited in the application see page 3, line 19 - page 4, line 32; figure 2 ---	1,2,4-6
Y	US 4 617 637 A (CHU RAYMOND D. ET AL) 14 October 1986 see column 3, line 53 - column 7, line 61 see column 8, line 27 - column 11, line 33; figures 1-4,6,7 ---	1,2,4-6
A	DE 42 18 782 A (ZAHNRADFABRIK FRIEDRICHSHAFEN) 14 January 1993 see the whole document --- -/--	1,5

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

2

Date of the actual completion of the international search	Date of mailing of the international search report
16 April 1997	24.04.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Nettesheim, J

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/BG 96/00017

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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2

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International Application No
PCT/BG 96/00017

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